Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AIR TRANSPORTATION SAFETY INVESTIGATION REPORT A19C0038

Fuel exhaustion

Keewatin Air LP
Beechcraft B200, C-FRMV
Gillam, Manitoba
24 April 2019

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FUEL EXHAUSTION

Keewatin Air LP
Beechcraft B200, C-FRMV
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24 April 2019

Summary

On 24 April 2019, the Keewatin Air LP Beechcraft B200 aircraft (registration C-FRMV, serial number BB979), equipped to perform medical evacuation flights, was conducting an instrument flight rules positioning flight (flight KEW202), with 2 flight crew members and 2 flight nurses on board, from Winnipeg/James Armstrong Richardson International Airport, Manitoba, to Rankin Inlet Airport, Nunavut, with a stop at Churchill Airport, Manitoba.

At 1814 Central Daylight Time, when the aircraft was cruising at flight level 250, the flight crew declared an emergency due to a fuel issue. The flight crew diverted to Gillam Airport, Manitoba, and initiated an emergency descent. During the descent, both engines flamed out. The flight crew attempted a forced landing on Runway 23, but the aircraft touched down on the frozen surface of Stephens Lake, 750 feet before the threshold of Runway 23. The landing gear was fully extended. The aircraft struck the rocky lake shore and travelled up the bank toward the runway area. It came to rest 190 feet before the threshold of Runway 23 at 1823:45 Central Daylight Time. None of the occupants was injured. The aircraft sustained substantial damage. The 406 MHz emergency locator transmitter activated. Emergency services responded. There was no fire.

1.0 FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Background

The day before the occurrence, on 23 April 2019, the Keewatin Air LP (Keewatin Air) Beechcraft B200 aircraft (registration C-FRMV, serial number BB979) had conducted a flight from Baker Lake Airport (CYBK), Nunavut, to Winnipeg/James Armstrong Richardson

International Airport (CYWG), Manitoba. After the flight, the flight crew could not find a fuel technician to refuel the aircraft. Because maintenance work was scheduled to be performed on the aircraft, the flight crew, who were at the end of their duty day, left the airport. Maintenance personnel replaced the fuel nozzles of the right engine and completed the necessary engine runs. The aircraft was not refuelled after the maintenance work was completed.

1.1.2 Occurrence flight

At approximately 1500[1] on 24 April, the occurrence flight crew—a line indoctrination captain and a captain in training—reported to the Keewatin Air hangar to conduct an instrument flight rules (IFR) positioning flight to Rankin Inlet Airport (CYRT), Nunavut, with 2 flight nurses on board. The flight would include a stop at Churchill Airport (CYYQ), Manitoba, to drop off one of the flight nurses. The flight was also part of line indoctrination training, which would continue for the following 2 weeks while the aircraft and the flight crew were based at CYRT.

The line indoctrination captain assumed the duties of first officer (hereafter referred to as FO) and sat in the right seat. He had not been provided with the records of the captain in training's previous line indoctrination rotation. The captain in training had passed a pilot proficiency check (PPC) ride to upgrade to captain and was midway through the line indoctrination process. The FO considered the captain in training to be the pilot-in-command (PIC).

The captain in training assumed the duties of captain (hereafter referred to as captain) and sat in the left seat, then commenced flight planning procedures.

Using the Keewatin Air flight planning software, the captain calculated that the flight would require 2456 pounds of fuel. He wrote this quantity on the operational flight plan (OFP) in the Actual Fuel on board box of the Weight and Balance section. The OFP listed CYYQ as the destination with a distance of 541 nautical miles (NM) and an estimated time en route of 2 hours and 17 minutes. The alternate airport was listed as Gillam Airport (CYGX), Manitoba. The planned 2456 pounds of fuel was enough for approximately 3 hours and 55 minutes of flight time, which would have allowed for the flight to destination, diversion to the alternate airport, and enough fuel in reserve for 45 minutes of flight. This met the requirements stipulated in the *Canadian Aviation Regulations* (CARs).[2]

The FO conducted a pre-flight inspection of the aircraft. During the inspection, he noted that the aircraft had about 1600 pounds of fuel on board. Because he preferred to order fuel directly from a fuel technician, he went to the fuel office in the hangar, but could not find anyone to take the fuel order. Intending to return to the office later, he went to the lounge where he found out that the flight would be delayed pending the arrival of the 2nd flight nurse. While waiting for the flight nurse to arrive, the crew loaded some cases of bottled

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1 All times are Central Daylight Time (Coordinated Universal Time minus 5 hours).

2 Transport Canada, SOR/96-433, *Canadian Aviation Regulations*, paragraph 602.88(4)(a)(i).

water onto the aircraft. When the captain asked if the aircraft was ready for the flight, the FO replied that it was.

When the second flight nurse arrived, the flight crew and both flight nurses boarded the aircraft. The captain entered the flight plan data into the flight management system (FMS). The investigation was unable to determine if information about the quantity of fuel on board was entered into the FMS.

The flight crew completed the BEFORE START checklist. The last step on the checklist is to start the engine. The flight crew then taxied to a run-up area and began the AFTER START checklist. When the FO read out the checklist item FUEL QUANTITY, the captain responded with the text that was printed on the checklist, "SUFFICIENT/BALANCED,"[3] but he did not check the fuel quantity indicators. When the checklist was complete, the crew taxied to the runway. The aircraft departed CYWG at 1639, with the captain as the pilot flying (PF) and the FO as the pilot monitoring (PM).

Roughly 8 NM after the takeoff, while still in the climb, the captain performed a progressive fuel calculation.[4] He did not look at the fuel quantity indicators during the process. Instead, the distance of 533 NM was entered in the Distance to Destination box on the OFP. The captain entered the flight planned fuel load of 2456 pounds in the Fuel Required box. He then entered 2206 pounds in the Fuel Remaining box; a difference of 250 pounds. The captain also informed the Keewatin Air flight coordinator that the aircraft had sufficient fuel for 3 hours and 55 minutes of flight. The aircraft continued the climb and levelled off at flight level (FL) 250.[5] During the rest of the flight, neither pilot performed periodic scans of the fuel quantity indicators.

At 1813, when the aircraft was about 14 NM west-northwest of CYGX and still level at FL 250, the left fuel pressure (L FUEL PRESS) warning light illuminated, indicating low fuel. The warning was followed almost immediately by power surging in the left engine. The captain turned the boost pump ON, and noticed that the fuel quantity indicators were showing 0 pounds. The captain asked the FO about the fuel quantity, at which point the FO realized that he had forgotten to order fuel. The flight crew declared an emergency with the Winnipeg Area Control Centre (ACC) at 1814 and began an emergency descent. The weather conditions at CYYQ were marginal, so the decision was made to divert to the alternate aerodrome, CYGX; however, the aircraft continued on the same heading toward CYYQ for another 2 minutes (Figure 1).

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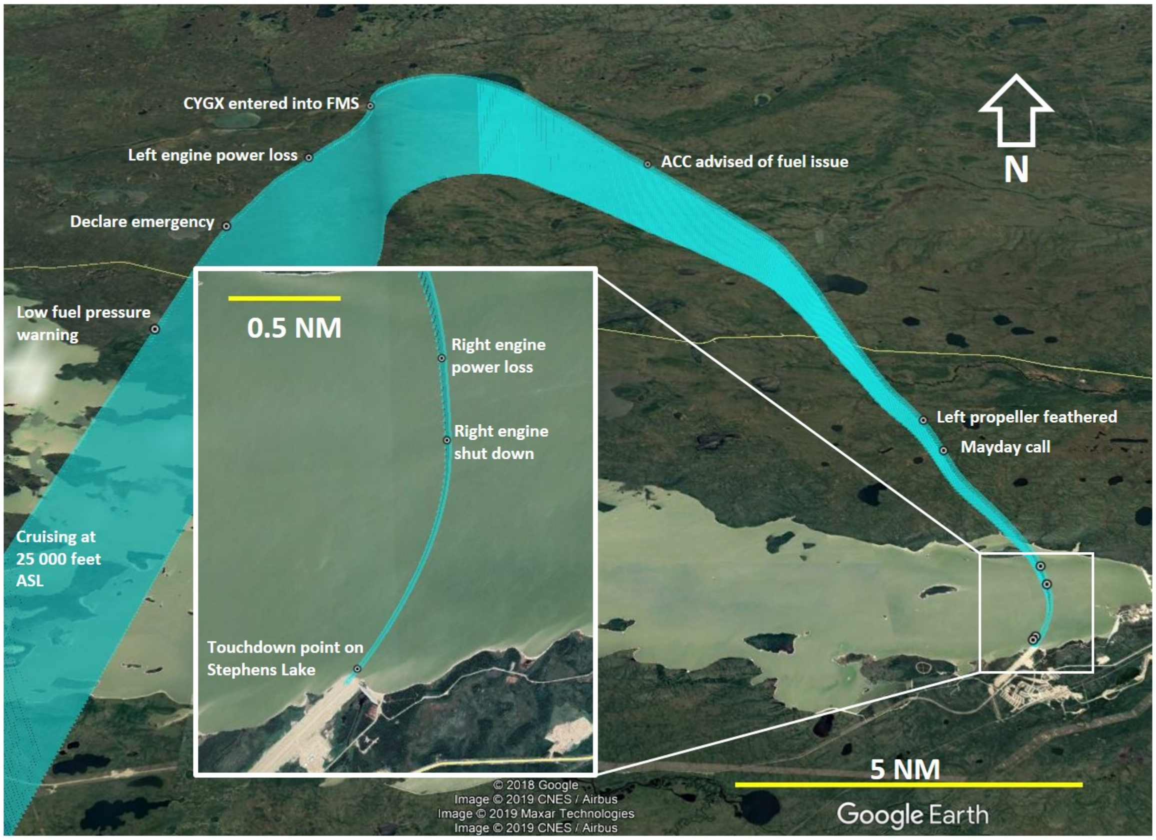
3 Keewatin Air LP / Nunavut Lifeline, Normal Checklist B-200 G1000 (10 January 2019).

4 Refer to section 1.18.1.2 for an explanation of progressive fuel calculations.

5 Flight level is the altitude expressed in hundreds of feet indicated on an altimeter set to 29.92 inches of mercury or 1013.2 millibars (mb). Flight level 250 represents a barometric altimeter indication of 25 000 feet above sea level.

Figure 1. Overlay of global positioning system data showing the aircraft's descent profile and key events (Source: Google Earth, with TSB annotations)



By 1815, when the aircraft was at FL 220, the left engine had exhausted its fuel supply and lost power. The crew conducted the EMERGENCY ENGINE SHUTDOWN procedure in the *Emergency and Abnormal Procedures Quick Reference Handbook* (QRH)[6] to shut down the engine; however, the left propeller continued to windmill[7] at speeds between 1300 and 2000 rpm[8] throughout the ensuing descent. At 1815:32, the FO programmed the FMS to display a track to CYGX and instructed the captain to turn right and follow the track. The FO moved the heading bugs, which were coupled on both FMS displays, to the CYGX heading. The captain then initiated a right turn toward CYGX.

The captain reduced the power setting of the right engine. From 1815 to 1818, the rate of descent varied between 3000 and 6000 fpm. The crew extended the landing gear in an attempt to set up a suitable descent angle to Runway 23. At 1817, the flight crew informed the ACC that the nature of the emergency was fuel related. The ACC provided the flight crew with the weather at CYGX and informed them that emergency services at CYGX would be

6 Keewatin Air LP, *Beechcraft King Air 200 Emergency and Abnormal Procedures Quick Reference Handbook*, Revision 0, p. E-2.

7 "The propeller windmilling at high speed in the low range of blade angles can produce an increase in parasitic drag." (Source: Federal Aviation Administration, FAA-H-8083-3B, *Airplane Flying Handbook* [2016], Chapter 12: Transition to Multiengine Airplanes, p. 12-3.)

8 The propellers were set to approximately 1660 rpm during the cruise portion of the flight.

notified. As the aircraft descended through approximately 5000 feet above sea level (ASL), the FO obtained a vertical navigation (VNAV) profile to Runway 23 on the FMS. The crew retracted the landing gear as the aircraft intercepted the VNAV path. At 1820, the ACC contacted the CYGX on-call operator and informed the operator of the emergency.

By 1820, the airspeed had decayed to approximately 100 knots and the captain was having difficulty controlling the aircraft. At times, the aircraft was descending below the VNAV path. Seeing this, the FO took over control and assumed the PF duties. At 1821, as the aircraft descended through 2800 feet ASL, the left propeller ceased windmilling as the rpm decreased from 1300 to 0 rpm. The flight crew made a Mayday call at 1821:30 on the CYGX mandatory frequency. When the aircraft was at approximately 2000 feet ASL, it descended below the cloud base and the FO was able to visually identify CYGX.

At 1822:34, when the aircraft was at 1300 feet ASL, roughly 835 feet above ground level (AGL), the right engine lost power. The aircraft could no longer maintain the VNAV path or a suitable visual approach to the runway. When the aircraft was at about 530 feet AGL and 1 NM from the runway, the crew shut down and feathered the right engine while continuing the right-hand curving visual approach to Runway 23 (Figure 1, inset).

The flaps remained up throughout the approach and subsequent landing. The crew selected the landing gear DOWN when the aircraft was at about 50 feet AGL and the aircraft touched down on the frozen surface of Stephens Lake with the landing gear fully extended (Figure 2).

Sufficient airspeed remained to enable the FO to raise the nose as the aircraft approached the rocky shoreline at the approach end of Runway 23. The aircraft struck the rocky shoreline in a nose-high attitude and skidded up onto the right edge of the runway area, coming to rest approximately 190 feet before the threshold (Figure 3).

The 406 MHz emergency locator transmitter (ELT) activated and the signal was received by the Canadian Mission Control Centre.

Figure 2. Marks made by the main landing gear on initial touchdown (Source: TSB)

Figure 3. The occurrence aircraft near the threshold of Runway 23 (Source: Royal Canadian Mounted Police)

1.2 Injuries to persons

There were no injuries.

1.3 Damage to aircraft

The aircraft sustained substantial damage.

1.4 Other damage

Several litres of hydraulic fluid from the fractured main landing gear legs were finely dispersed over the rocky shoreline and gravel area before the threshold of Runway 23. The gravel area received minor abrasion. There was no other damage to the environment.

1.5 Personnel information

1.5.1 General

The flight crew was certified and qualified for the flight in accordance with existing regulations.

The captain joined Keewatin Air as an FO in December 2017. He held a valid Canadian commercial pilot licence and was undergoing training to upgrade to captain. He had successfully completed a captain PPC on 16 March 2019. The first rotation of line indoctrination had taken place from 28 March to 06 April 2019. The occurrence flight was to be the start of the second 2-week period of line indoctrination. On the occurrence flight, he occupied the left seat and was to perform the duties of captain.

The FO joined Keewatin Air as a direct entry captain in August 2017. He held a valid Canadian airline transport pilot licence and had been appointed as a line indoctrination captain by Keewatin Air. He had successfully completed a captain PPC on 16 November 2018. On the occurrence flight, he occupied the right seat and was to perform the duties of FO. He would also be providing line indoctrination training to the captain during the occurrence flight and the subsequent 2-week deployment to CYRT.

According to company training records, the captain and FO had received crew resource management (CRM) training on 27 February 2019 and 08 November 2018, respectively, and both had received pilot decision making (PDM) training on 15 February 2019.

Table 1. Personnel information

	Captain	First officer
Pilot licence	Commercial pilot licence (CPL)	Airline transport pilot licence (ATPL)
Medical expiry date	01 June 2019	01 April 2020
Total flight hours	Approximately 1350	Approximately 3500
Total flight hours on type	Approximately 1100	Approximately 1350
Flight hours in the last 7 days	2.2	2.2
Flight hours in the last 30 days	72.0	84.2
Flight hours in the last 90 days	156.1	204.7
Flight hours on type in the last 90 days	156.1	204.7
Hours on duty	5.5	5.5

1.5.2 Flight crew fitness for duty

The flight crew members reported for work at approximately 1500 on 24 April 2019. They had arrived in Winnipeg the previous evening and had maintained a sleep-wake schedule consistent with a mid-afternoon work schedule. Their work schedule was not indicative of the potential for fatigue and, based on the information obtained, the flight crew began their shift rested. There is no indication that fatigue played a role in this occurrence.

1.6 Aircraft information

1.6.1 General

The Beechcraft King Air B200 is a pressurized, twin-engine, turboprop, fixed-wing aircraft manufactured by Beech Aircraft Corporation that can accommodate 7 passengers in the standard seating configuration. The occurrence aircraft was configured to conduct medical evacuation (MEDEVAC) flights with a crew of 2 pilots and a flight nurse. It was equipped with a Garmin G1000 integrated avionics FMS.

Records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. There were no outstanding defects at the time of the occurrence.

1.6.2 Fuel system

The aircraft has a fuel capacity of 544 U.S. gallons (3808 pounds).[9] The fuel system consists of 2 separate systems, 1 for each engine. Each system is further divided into a main and an auxiliary sub-system.[10]

For flight planning purposes, the fuel consumption for both engines combined is 800 pounds for the first hour, and 600 pounds per hour thereafter.

The main fuel tanks are filled through an opening near their respective wing tips. The auxiliary fuel tanks are located in the left and right wing centre sections, inboard of each nacelle. Each auxiliary tank has its own filler opening. The system will automatically transfer fuel from the auxiliary tanks first, requiring no action from the crew.

The aircraft is equipped with left and right fuel quantity indicators that show the quantity of fuel in pounds. The 2 fuel quantity indicators are mounted in the fuel system panel on the left side of the cockpit. The fuel quantity indicators are not easily seen from the right seat, especially if the left seat pilot's hands are on the control wheel. A switch on the fuel panel changes the display to show the quantity in either both main tanks or both auxiliary tanks.

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9 At 15 °C, 1 U.S. gallon of Jet A-1 fuel weighs 7 pounds. (Source: Transport Canada, TP 14371, *Transport Canada Aeronautical Information Manual* [28 March 2019], RAC – Rules of the Air and Air Traffic Services, section 3.4.8, Table 3.4.)

10 Raytheon Aircraft Company, *Beechcraft Super King Air® B200 & B200C Pilot's Operating Handbook and FAA Approved Flight Manual*, Revision C9 (August 2004), section VII: Systems Description, p. 7-31.

The Garmin 1000 system allows the crew to enter the actual quantity of fuel on board before departure. Using in-flight fuel consumption data, the system is able to display the estimated quantity of fuel remaining at landing.

The aircraft is not equipped with a low-fuel-quantity warning system. As a result, apart from the fuel quantity indicators, the first indication of fuel exhaustion is the illumination of the respective low-fuel-pressure warning light in the central annunciator panel, which is caused by the reduced fuel pressure due to the lack of useable fuel.

1.7 Meteorological information

The CYYQ aerodrome forecast (TAF) issued at 1525 and valid for the estimated time of arrival indicated that the weather conditions would likely be as follows:

- wind 340° T at 20 knots, gusting to 30 knots
- visibility 6 statute miles (SM) in light rain and snow
- a broken ceiling at 1200 feet AGL and an overcast layer at 2000 feet AGL.

Between 1800 and 2100 there would be a temporary change to:

- visibility 1 ½ SM in light snow showers
- an overcast ceiling of 800 feet AGL.

Between 1900 to 2100, there would be a 30% probability of:

- visibility 4 SM in light freezing rain, and mist.

The occurrence flight landed on Stephens Lake at about 1823. An aerodrome special meteorological report (SPECI) was issued at CYGX at 1840, which indicated that at the time of the occurrence the following conditions likely existed:

- wind 280°T at 11 knots
- visibility 15 SM
- overcast clouds at 2000 feet AGL
- temperature 5 °C, dew point 3 °C
- altimeter setting 29.46 inches of mercury

1.8 Aids to navigation

Not applicable.

1.9 Communication

Not applicable.

1.10 Aerodrome information

CYGX is operated by the Town of Gillam and consists of a 5034 foot gravel runway (05/23). The approach to Runway 23 is over Stephens Lake and the threshold is 474 feet ASL, which is roughly 12 feet higher than the occurrence aircraft's initial touchdown point on the ice.

Emergency services are provided by the Town of Gillam on a call-out basis, and are located about 1 SM from the airport gate. The airport is operational 24 hours a day, 7 days a week. After normal business hours, call-out procedures have been established and an on-call operator is responsible for initiating the emergency response plan.

1.11 Flight recorders

The aircraft was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR) and neither was required by regulation. However, the Garmin G1000 system recorded data on a secure digital (SD) card and provided the investigation with information about the flight path, engine operation, radio tuning and navigation selections.

1.11.1 TSB recommendation on the mandatory installation of lightweight flight recording systems

The TSB has investigated a number of accidents[11] in which a lack of data precluded the determination of findings as to cause and contributing factors. One such investigation[12] involved a privately operated Cessna Citation 500 that crashed shortly after takeoff on 13 October 2016. There were no survivors. The aircraft was not equipped with a CVR or FDR.

As a result of that accident, the Board recommended that

> the Department of Transport require the installation of lightweight flight recording systems by commercial operators and private operators not currently not required to carry these systems.
>
> **TSB Recommendation A18-01**

In October 2019, Transport Canada (TC) provided an update on the activities of the Focus Group on Lightweight Data Recorders (LDR) and its next meeting, planned for March 2020.

The TSB considers TC's efforts to continue to work with industry through the focus group to be a positive action. However, TC's long-term objective of potentially developing regulations for commercial and private operators that are currently not required to carry LDRs indicates that TC may not regulate that requirement. Additionally, no specific timeline has been provided for the completion of the focus group activities and any subsequent regulatory implementation.

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[11] TSB aviation investigation reports A01W0261, A02W0173, A03H0002, A05W0137, A05C0187, A06W0139, A07Q0063, A07W0150, A09A0036, A09P0187, A10P0244, A11P0117, A11Q0028, A11O0031, A11W0048, A11C0047, A11P0106, A11H0001, A12C0005, A12W0031, A13H0002, A14W0127, A14Q0148, A15P0081, A16A0032, A16P0186, A17C0132, A17Q0050, A17P0149, A17W0172, A18O0134, A18O0150, and A18P0031.

[12] TSB Aviation Investigation Report A16P0186.

The TSB has consequently assessed TC's response to Recommendation A18-01 to be **Satisfactory in Part**.[13]

1.12 Wreckage and impact information

The aircraft struck the frozen surface of Stephens Lake with the landing gear fully extended and the flaps retracted. On contact with a rocky berm, the lower portions of both main landing gear legs were torn away, damaging both nacelles and the lower surfaces of both wings. The main fuel-feed pipes in both nacelles were severed when the main landing gear trunnion attachments failed. However, there was no fuel spillage.

The nose landing gear remained attached and extended. The fuselage was creased aft of the main cabin door. The underside of the fuselage was damaged due to contact with the rocky berm. The main wing spar exhibited permanent deflection in the centre section. One propeller was damaged due to contact with the ground.

The over-wing emergency exit was operational. The main cabin door could be opened, but laid horizontally on the ground due to the loss of the main landing gear legs. The crew and cabin seating remained attached to the aircraft structure. Examination of the wreckage did not detect the presence of any fuel beyond residual amounts.

The ELT (Artex Model ME-406, part number 453-6603) remained secure in the mounting bracket during the impact sequence. The antenna cable and the connector plug for the remote switch were found securely attached.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 General

The aircraft cockpit and cabin remained intact and provided a survivable space. Both pilots were wearing 4-point restraint systems. Both flight nurses were wearing the 3-point restraint systems provided on the sideways-mounted, bench-style passenger seats.

The occupants were able to open the over-wing exit, which is on the right-hand side; however, they chose to exit through the main cabin door. The main cabin door opened

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[13] A **Satisfactory in Part** rating is assigned if the planned action or the action taken will reduce but not substantially reduce or eliminate the deficiency, and meaningful progress has been made since the recommendation was issued. The TSB will follow up with the respondent as to options that could further mitigate the risks associated with the deficiency. The TSB will reassess the deficiency on an annual basis or when otherwise warranted.

partially, and was lying on the ground due to the damaged main landing gear, but it still provided an unimpeded exit.

1.15.2 Emergency response

At 1820, the on-call operator at CYGX received a call from the Winnipeg ACC to report that an aircraft had declared an emergency due to a fuel issue. When the operator arrived at the crash site at 1826, about 2 to 3 minutes after the aircraft came to rest, the occupants were already standing outside the aircraft. The airport manager arrived at 1855. The crew advised that they were not injured and did not require medical assistance, and that there was no concern about fuel leakage or fire.

At approximately 1906, the airport manager contacted the local RCMP (Royal Canadian Mounted Police) detachment, who instructed RCMP dispatch to notify the Town of Gillam emergency medical services (EMS) and fire department. EMS and the fire department were notified at 1921 and 1922, respectively. EMS arrived on scene at about 1922, approximately 1 hour after the initial call from the ACC to the CYGX on-call operator. The fire department arrived a short time later after experiencing difficulty opening the airport gate.

EMS transported the flight crew and flight nurses to Gillam Hospital. The fire department surveyed the aircraft and disconnected the aircraft batteries.

1.16 Tests and research

Not applicable.

1.17 Organizational and management information

1.17.1 Operator

Keewatin Air operates primarily in the Arctic under CARs Subpart 703 (Air Taxi Operations), and 704 (Commuter Operations). The company provides charter services, but its primary focus is medical transportation and air ambulance services. The company operations manual (COM) details the policies and procedures to be followed by operations personnel in the conduct of their duties.[14]

[14] Keewatin Air LP, *Company Operations Manual For 703 – Air Taxi Operations, 704 – Commuter Operations*, Re-issue (15 January 2018), section 3.5: Duties, Responsibilities and Succession of Command – Operations Personnel, pp. 3-8 to 3-11.

1.17.2 Line indoctrination

1.17.2.1 General

Line indoctrination training is not a regulatory requirement for CARs Subpart 703 operators. However, Keewatin Air implemented mandatory line indoctrination training for pilots flying aircraft in accordance with CARs Subpart 703 to align its 703 and 704 operations. The flight crew training manual (FCTM) specifies how line indoctrination is to be conducted.[15] To function effectively in a line indoctrination environment, flight crews must have clearly defined roles and responsibilities. To ensure timely decision making, it must be clear to both crew members who is the PIC.

1.17.2.2 Line indoctrination candidate

According to Keewatin Air's FCTM, a line indoctrination candidate must have completed initial training and a PPC.[16] The FCTM lists the requirements for initial line indoctrination training on turboprop aircraft as follows:

> a) Each pilot shall demonstrate knowledge of, as applicable, a mandatory list of operating maneuvers and procedures as detailed in Section 4.3.2 and complete 20 flying hours and 4 mandatory sectors – 2 sectors as Pilot Flying (PF) and 2 as Pilot Monitoring (PM);
>
> b) After completing the 4 mandatory sectors, the remaining time may be reduced by 1 hour for each additional sector flown to a maximum 50% reduction of the original time requirement.[17]

As described in the FCTM, "[a] sector includes a takeoff, departure, arrival, and landing including a minimum of 50 nm en route segment for CAR[s] 704 operations."[18]

1.17.2.3 Line indoctrination captain

Line indoctrination captain is a term used by Keewatin Air to refer to a captain who has been authorised to conduct line indoctrination training. The FCTM refers to the person conducting the line indoctrination as a training pilot. When conducting a line indoctrination Keewatin Air states that the training pilot will be the PIC.

When a line indoctrination captain position becomes available at Keewatin Air, a notice is posted internally and interested candidates notify the training manager. After an

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[15] Keewatin Air LP, *Flight Crew Training Manual For 703 – Air Taxi Operations, 704 – Commuter Operations*, Amendment 3 (01 July 2018), section 4.3: Line Indoctrination, pp. 4-20 to 4-23.

[16] Ibid., section 4.3.1: General, p. 4-20.

[17] Ibid., section 4.3.3.3: Specific Requirements for Initial Line Indoctrination, p. 4-23.

[18] Ibid., section 4.3.3.1: General, p. 4-22.

assessment and, if deemed necessary, a line check, the chosen candidate undergoes familiarization training on the role and associated record keeping. This training is provided by the chief pilot or training manager. There is no certification document issued or entry made in the pilot's training record. However, once the training has been completed, the pilot is identified as a line indoctrination captain in a Keewatin Air pilot status spreadsheet.

1.17.2.4 Roles and responsibilities

Training pilots must record details of each flight on a form with accompanying remarks. Candidates are to keep the form in their possession during line indoctrination. When the line indoctrination training is complete, training pilots must forward the form to the chief pilot.[19]

Training pilots must also provide the chief pilot and flight training manager with "a verbal or written update on the candidate's progress after every ten (10) hours of line indoctrination."[20] In addition, the flight training manager is expected to receive daily reports from the training pilots, as well as weekly submissions of the line indoctrination form. The flight training manager would then provide the form to the candidate's next training pilot. These expectations were communicated to training pilots in an email from the flight training manager; they were not documented in the FCTM.

1.17.2.4.1 Occurrence flight responsibilities

The flight schedule designated the occurrence flight as a line indoctrination flight. However, the FO had not been provided with the records from the captain's previous line indoctrination training. The crew established between themselves that the captain would do the flight planning and that the FO would carry out the pre-flight inspection.

1.17.3 Pre-flight briefing

Briefings are completed before departure to ensure that all flight crew members have the knowledge and information necessary to develop shared mental models of the flight and to perform their assigned duties successfully.

The Keewatin Air standard operating procedures (SOPs) for the Beechcraft King Air 200 aircraft state the following with respect to crew briefings:

> As a minimum the following information should be provided to all crew members in sufficient detail to facilitate performance of their duties.
>
> - weather for departure, en route, destination, and alternative destinations;

19 Ibid., section 8.4.1: General, p. 8-27.

20 Ibid.

- aircraft fuel load and configuration;
- flight time, route to be flown, and any work to be carried out;
- preferred alternate for patient considerations;
- duties in addition to those specified in these SOPs and other directives.[21]

Although the SOPs provide a list of topics to be discussed in a pre-flight briefing, there is no standard crew briefing, such as pre-flight briefing card or form.

The COM requires the PIC to provide briefings to the second-in-command[22] and the medical crew[23] regarding the flight routing and anticipated flight conditions. There is no specific requirement to discuss the fuel load in these briefings.

Normally, flight nurses are considered medical crew members for MEDEVAC flights; however, the 2 flight nurses on the occurrence flight did not take part in any pre-flight briefings because this particular flight was considered a positioning flight, not an actual MEDEVAC flight. The flight nurses were being flown to their respective work sites, and the flight crew considered them to be passengers.

1.18 Additional information

1.18.1 Fuelling procedures

The fuel office at CYWG is located on the ground floor in the Keewatin Air hangar. To order fuel, pilots normally phone or visit the office and request fuel from a fuel technician. Pilots can also place a fuel order through the Keewatin Air dispatcher, who would then relay the order to the fuel office. When based away from CYWG, aircraft would normally be refuelled after each flight to expedite departures in the event of a MEDEVAC call. Hence, refuelling was not always required as part of the pre-flight task sequence.

1.18.1.1 Quantity of fuel at departure

The investigation performed calculations based on the last time the aircraft's fuel tanks were known to be full. The last known uplift of fuel that filled the fuel tanks to full was made at CYWG at the end of the flying day on 20 April. The aircraft then made a number of flights on 22 and 23 April. During this time, 1223.3 L of fuel was uplifted at CYRT on 22 April, and

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21 Keewatin Air LP, *Beechcraft King Air 200 Aircraft Standard Operating Procedures (SOP)*, Amendment 1 (19 June 2017), section 2.1.5: Crew Briefing, p. 40.

22 Keewatin Air LP, *Company Operations Manual For 703 – Air Taxi Operations, 704 – Commuter Operations*, Re-issue (15 January 2018), section 7.9.1: Flight Crew Member Safety Pre-Flight Briefing and Post-Flight Briefing, p. 7-28.

23 Ibid., section 5.7.1.1: General, p. 5-29.

then 896 L of fuel was uplifted at CYBK on 23 April. This equates to 2263 pounds and 1658 pounds, respectively.[24] The aircraft returned to CYWG on 23 April, and was not refuelled.

Based on the time flown and quantity of fuel uplifted since 20 April, the investigation determined that there could have been as little as 1300 pounds of fuel remaining on board. During the pre-flight inspection, the FO determined that there was approximately 1600 pounds of fuel on board.

1.18.1.2 Progressive fuel calculation

The purpose of a progressive fuel calculation is to verify, once level in cruise flight, that the quantity of fuel remaining on board the aircraft is sufficient to safely continue the flight as planned. It is one of the items listed on the CRUISE checklist. The OFP has 3 boxes in which to record the results of the calculation. They are labelled as follows:

- Distance to Destination
- Fuel Required
- Fuel Remaining

For the progressive fuel calculation to be accurate, it is important that the value entered in the Fuel Remaining box be obtained from the fuel quantity indicators. If the value is obtained from the FMS display instead, then an incorrect FMS fuel on board entry made during flight planning will not be detected, and the calculations will be based on incorrect information. Likewise, calculating the fuel remaining from the flight-planned fuel quantity will not detect if the aircraft received insufficient fuel during the last refuelling.

Neither the cruise procedure in the SOPs nor the OFP provides instructions with respect to which data sources to use, or how the calculation is to be carried out.

1.18.2 Checklists

1.18.2.1 General

Checklists guide pilot actions during normal, abnormal, and emergency operations. They are designed to ensure steps are followed in a specific order and without omission. However, checklists do not guarantee a fail-safe operation. To be effective, checklists must be specific and unambiguous, and pilots must be trained on their proper use.

Some checklists are published in aircraft documents, such as the pilot's operating handbook or the approved aircraft flight manual. In addition, air operators will typically produce their own checklist procedures in their SOPs or QRH. At Keewatin Air, laminated copies of the normal checklists are carried in the cockpit.

The COM states that:

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[24] At 15 °C, 1 L of Jet A-1 fuel weighs 1.85 pounds. (Source: Transport Canada, TP 14371, *Transport Canada Aeronautical Information Manual* [28 March 2019], RAC – Rules of the Air and Air Traffic Services, section 3.4.8, Table 3.4.)

> Company-developed aircraft checklists meet and/or exceed manufacturer's checklists and have been developed to enable the aircraft to be operated in accordance with the limitations specified in the Aircraft Flight Manual (AFM), Aircraft Operating Manual (AOM), Pilot Operating Handbook (POH), Standard Operating Procedures (SOPs) or any equivalent document.[25]

On the occurrence flight, the flight crew used the 2-sided, single-page, laminated Normal Checklist B-200 G1000 and the *Beechcraft King Air 200 Emergency and Abnormal Procedures Quick Reference Handbook*.

1.18.2.2 Keewatin Air—Normal Checklist B-200 G1000

The Normal Checklist B-200 G1000 has 2 references to fuel quantity (Appendix A):

1. The 2nd item on the AFTER START checklist is FUEL QUANTITY. This item provides SUFFICIENT/BALANCED as a response, which prompts pilots to confirm the fuel quantity on board, compare it to the fuel required and ensure that fuel on board is balanced between tanks.
2. The fourth item on the CRUISE checklist is FUEL. This item provides PROGRESSIVE FUEL Calc. as the response, which prompts the pilots to perform progressive fuel calculations.[26]

1.18.2.3 Keewatin Air—*Beechcraft King Air 200 Emergency and Abnormal Procedures Quick Reference Handbook*

In an emergency or abnormal situation, pilots will refer to the QRH. It contains 2 procedures related to the fuel system: CROSSFEED (ONE-ENGINE-INOPERATIVE OPERATION) and AUXILIARY FUEL TRANSFER FAILURE (NO TRANSFER LIGHT). The QRH does not contain any procedures related to a fuel exhaustion emergency.

In addition, the QRH contains the following procedure for the flight crew to follow in case of an engine failure.

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[25] Keewatin Air LP, *Company Operations Manual For 703 – Air Taxi Operations, 704 – Commuter Operations*, Re-issue (15 January 2018), section 7.10.2: Aircraft Checklists, p. 7-39.

[26] Refer to section 1.18.1.2 of this report for an explanation on progressive fuel calculations.

Figure 4. Keewatin B200 engine failure Quick Reference Handbook procedure (Source: Keewatin Air LP)

- **ENGINE FAILURE IN FLIGHT**

Affected Engine:

1. **AP/YD DISC/TRIM INTRPT Button (if engaged) .... PRESS and RELEASE**
2. **Condition Lever .... FUEL CUTOFF**
3. **Prop Lever .... FEATHER**
4. **Firewall Shutoff Valve .... CLOSE**
5. **Fire Extinguisher (if installed) (if fire warning persists) .... ACTUATE**
6. Trim Tabs .... MANUALLY ADJUST ELEVATOR, AILERON, and RUDDER TABS
7. Autopilot .... PRESS 'AP' BUTTON (if desired) to RE-ENGAGE
8. Rudder Tab .... MANUALLY ADJUST AS REQUIRED AFTER POWER and CONFIGURATION CHANGES
9. TCAS II (if installed) .... SELECT TA ONLY
10. Generator .... OFF
11. Auto Ignition .... OFF
12. Autofeather (if installed) .... OFF
13. Brake Deice (if installed) .... OFF
14. Electrical Load .... MONITOR

Keewatin's procedure is that bolded items of the checklist are to be completed by memory and followed up by confirmation using the checklist.

1.18.2.4 Beechcraft—*Pilot's Check List—Normal Procedures*

The Beechcraft *Pilot's Check List—Normal Procedures* is not routinely used by Keewatin Air pilots, but it is carried in the aircraft. After its PREFLIGHT INSPECTION section, the document contains the following 3 fuel-related items that are not included in the Keewatin Air – *Normal Checklist B-200 G1000* checklist, which was used on the occurrence flight:

1. Item 27 j. on the BEFORE ENGINE STARTING checklist is Fuel Quantity (Mains and Auxiliary). This item provides CHECK as the response.[27]

[27] Beechcraft, *Pilot's Check List—Normal Procedures Super King Air B200 & B200C* (July 1996), p. N-11.

2. Item 14 on the BEFORE TAKEOFF (Runup) checklist is Fuel Quantity, Flight and Engine Instruments. This item provides CHECK as the response.[28]
3. Item 6 on the DESCENT checklist is Fuel Balance. This item provides CHECK as the response.[29]

1.18.2.5 Fuel monitoring

The COM states the following with respect to fuel monitoring:

> All personnel involved in the fueling, dispatch and conduct of a flight must be vigilant in ensuring that the required fuel is on board the aircraft. Flight crew members must closely monitor the fuel status throughout the flight and be alert to any conditions that could deplete fuel reserves. If there is any indication of a malfunction with the fuel system, it is crucial that the problem be correctly identified and that the proper checklist is followed.
>
> Fuel monitoring shall be recorded on the Operational Flight Plan (OFP) for all flights with the following exceptions:
>
> a) Those flights that terminate at the point of departure, for example: training flights, maintenance test flights, in-flight emergencies.
>
> b) Flights that have a duration of less than sixty (60 or 1.0) minutes.[30]

The SOP states that:

> Periodically during cruise, but no less than once every 30 minutes, each flight crew member shall carry out a visual check of the displays and controls on the flight deck. Should an inappropriate condition be found the applicable action shall be taken. These items include indicators, annunciators, pressurization, fuel distribution & balance. This list is not exhaustive.[31]

1.18.3 Human factors

1.18.3.1 Crew resource management

Training in CRM develops cognitive and interpersonal skills, such as effective communications and behaviours associated with teamwork, and provides crew members with strategies to ensure they use all available resources to develop their shared mental models of the flight. The aim of CRM training is to increase awareness of human error and

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[28] Ibid., p. N-17.

[29] Ibid., p. N-20.

[30] Keewatin Air LP, *Company Operations Manual For 703 – Air Taxi Operations, 704 – Commuter Operations*, Re-issue (15 January 2018), section 4.11.2: Progressive Monitoring of Fuel During Flight, p. 4-29.

[31] Keewatin Air LP, *Beechcraft King Air 200 Aircraft Standard Operating Procedures (SOP)*, Amendment 1 (19 June 2017), section 2.5.3: Periodic Checks, p. 64.

organizational threats, and discuss techniques, skills and attitudes to minimize their effects.[32]

1.18.3.2 Situation awareness and mental models

Situation assessment is the process of acquiring data to understand or obtain a mental picture of the immediate environment.[33] Operators develop mental models of system state based on their training and experience with the system, and on the available information that they obtain.

Situation awareness is described as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the future."[34] It refers to person's understanding or mental picture of that environment. This awareness is characterized by the individual's perception of the environment, the manner in which information is processed so that the individual fully understands its meaning, and the projection of this information into the future.[35]

Flight crew members' shared situation awareness[36,37] refers to how each pilot's awareness of the situation needs to be consistent with that of the other pilot. With a common understanding, flight crew members can effectively anticipate and coordinate their actions to perform in a coordinated, efficient, and safe manner to manage threats.

Mitigations are in place to ensure flight crews develop, maintain and update these shared mental models, such as CRM, effective flight planning, in-flight briefings, communications techniques, and SOPs. Other mitigations are also typically in place to ensure any anomalies in the shared mental models are detected and rectified. These mitigations include the use of checklists and the execution of cockpit instrument scans.

1.18.3.3 Performance reliability

As pilots gain experience and practice in a certain routine, they develop automatic skilled performance that requires less cognitive effort to perform each step. For example, the pre-

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32 Transport Canada, *Development and Implementation of an Advanced Qualification Program (AQP)* (May 2010), Chapter 7: Crew Resource Management (CRM), section 7.1.1: Overview, at https://www.tc.gc.ca/eng/civilaviation/standards/commerce-aqp-chapter7-section1-1083.htm#711 (last accessed on 16 July 2020).

33 M.R. Endsley, "Toward a Theory of Situation Awareness in Dynamic Systems," in *Human Factors Journal*, Vol. 37, No. 1 (1995), pp. 32–64.

34 M.R. Endsley, *The Functioning and Evaluation of Pilot Situation Awareness*, Northrop technical report: NOR DOC 88–30 (1988), as cited in M.R. Endsley, "Situation Awareness in Aviation Systems", in J.A. Wise, V.D. Hopkin, and D.J. Garland (Eds.), *Handbook of Aviation Human Factors* (2010), Chapter 12, pp.12-1 – 12-22.

35 M.R. Endsley, "Design and Evaluation for Situation Awareness Enhancement," presented in January 1988 at the Proceedings of the Human Factors Society 32nd Annual Meeting, Santa Monica, CA, pp. 97–101.

36 M.R. Endsley, "Toward a Theory of Situation Awareness in Dynamic Systems", in *Human Factors* Vol. 37, No. 1 (1995), pp. 32–64.

37 E. Salas, C. Prince, D.P. Baker, and L. Shrestha, "Situation Awareness in Team Performance: Implications for Measurement and Training," *Human Factors* Vol. 37, No. 1 (1995), pp. 123–136.

flight walk around becomes routine because it is performed before each flight. During routine skilled performance, each step in the sequence automatically prompts the next step in the sequence with minimal use of attention resources. However, if a new or less-routine task is placed in the sequence, more resources will be required to ensure that the task is performed. In such situations, memory aids, an additional point in the checklist or prompting from other flight crew members could help ensure the task is remembered. If such resources are not used, especially in the presence of distractions or interruptions, pilots may inadvertently return to following the familiar skilled sequence, omitting the new task.

Without the use of memory aids or other prompts, the performance of a new or less-familiar task will depend on the individual's prospective memory. Prospective memory is remembering to perform an intended action in the future and has 4 stages: encoding, retention, execution and evaluation. When an intentional action has been successfully encoded and retained, then subsequent execution of the intended action relies firstly on its retrieval.

Retrieving an intended action at the correct time will entirely depend on the individual's attentional resources, and working and long-term memories. Use of attention resources and working memory is highly vulnerable to the effects of workload and distraction, increasing the risk of lapse errors.[38,39]

If a new or less-routine task is not included in any verification methods, such as the cockpit checklist, omission of the task is less likely to be detected.

1.18.3.4 Startle effect

In aviation, the startle effect can be defined as an uncontrollable, automatic reflex that is elicited by exposure to a sudden, intense event that violates a pilot's expectations.[40] Research shows that "[t]he effects of startle, an autonomic reaction with deleterious effects on information processing, may be a strong contributor to poor pilot performance during critical events."[41] These effects may seriously impair cognitive processing and decision-making, all critical skills in the handling of an emergency.

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[38] Lapses involve failures of memory.

[39] C.D. Wickens, J.G. Hollands, S. Banbury, R. Parasuraman, *Engineering Psychology and Human Performance*, (New York: Routledge, Taylor and Francis Group, 2016), Fourth Edition, pp. 3–6.

[40] Federal Aviation Administration, Advisory Circular 120–111, *Upset Prevention and Recovery Training* (14 April 2015), p. 3.

[41] W. Martin, P. Murray, and P. Bates, *The Effects of Startle on Pilots During Critical Events: A Case Study Analysis* (2012), at www98.griffith.edu.au (last accessed on 17 July 2020).

CRM and PDM training approaches may be helpful to further prepare pilots for unexpected, unusual, or distracting events and enhance their ability to quickly recover from them. For instance, there is evidence that training for judgment skills can improve a pilot's ability to recognize and adapt to unexpected events.[42]

1.18.3.5 Workload and experience

Flight crews operate in a complex environment where there are multiple sources and types of information to monitor and keep track of. At the same time, human attention and the capacity to process information are limited. Workload is a function of the number of tasks that must be completed within a given amount of time. If the number of tasks that must be completed increases, or if time available decreases, workload increases.[43] Workload may also be defined as the demand for mental resources.[44]

Because human resources are limited, the level of resources needed for a specific task can exceed the amount available. People operating under conditions of high workload can become task-saturated or overloaded, and may channel their attention, concentrating on some tasks at the expense of others. In a time-critical situation, high workload can lead to human error or delayed decisions to accommodate the processing of relevant information.

Managing an increased workload depends on the person's experience with the task, training and relevant skill levels. When learning a role, competence will develop along a continuum from novice, not yet competent, proficient, and expert. In moving across this continuum, learners proceed through a series of predictable stages. When a minimal level of competence is attained, learners can be at a stage where tasks may be performed effectively but require a significant level of attentional resources. As learners become proficient or expert, tasks become more automatic and require fewer attentional resources.[45]

1.19 Useful or effective investigation techniques

Not applicable.

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[42] J. A. Kochan, *The Role of Domain Expertise and Judgment in Dealing with Unexpected Events* (Doctoral dissertation). University of Central Florida, Orlando, (2005).

[43] A.D. Andre, "The Value of Workload in the Design and Analysis of Consumer Products," in: P.A. Hancock and P.A. Desmond (eds.), *Stress, Workload and Fatigue*, Human Factors in Transportation series (Abingdon, UK: CRC Press, 2001), pp. 373–383.

[44] C.D. Wickens, "Processing Resources in Attention, Dual Task Performance, and Workload Assessment," prepared for Office of Naval Research Engineering Psychology Program (July 1981).

[45] Dreyfus, Stuart E.; Dreyfus, Hubert L. *Mind Over Machine*, *The power of human intuition and expertise in the era of the computer*, (The Free Press New York, 1986), pp. 16–51.

2.0 ANALYSIS

The investigation determined that no aircraft system failures or malfunctions contributed to the accident. During the early stages of the investigation, it became apparent that the aircraft departed Winnipeg/James Armstrong Richardson International Airport (CYWG), Manitoba, with insufficient fuel on board for the planned flight to Churchill Airport (CYYQ), Manitoba. This analysis will focus on why the flight crew departed CYWG with insufficient fuel on board the aircraft, and the flight crew's handling of the resulting emergency. The analysis will conclude with a brief discussion of the airport's emergency services response.

2.1 Pre-flight fuel state

The Keewatin Air standard operating procedures (SOPs) for the Beechcraft King Air 200 aircraft do not specify that the aircraft should be refuelled at the end of each flight; however, refuelling by the last crew to fly an aircraft was an accepted practice at Keewatin Air, both to expedite departures in the event of a medical evacuation (MEDEVAC) call and as a courtesy to the first flight crew the next day. As a result, the requirement to refuel the aircraft was not always required as of part of the pre-flight task sequence.

In this occurrence, the line indoctrination pilot had assumed the role of first officer (FO); he performed the pre-flight inspection and determined that the aircraft required fuel. This differed from the usual practice in which the aircraft would have been fuelled following the previous flight. The FO went to the fuel office to request fuel but when he could not find anyone to take the fuel order, he left with the intention of returning later. However, after finding out that the flight would be delayed pending the arrival of the 2nd flight nurse, the FO went to load supplies onto the aircraft, and did not return to the fuel office. When the captain asked if the aircraft was ready, the FO replied that it was, not recalling that it required fuel. The FO realized that he had forgotten to have the aircraft fuelled only after the left fuel pressure (L FUEL PRESS) warning light illuminated.

2.2 Aircraft fuel management

2.2.1 Flight management system

The fuel quantity data entered into the flight management system (FMS) would normally be the actual fuel quantity on board the aircraft, not the quantity of fuel planned for the flight. The investigation was unable to determine if any information about the fuel quantity was entered into the FMS; however, if the actual quantity of fuel had been entered, an incorrect quantity of fuel would have been displayed for the quantity to destination. Because nothing was out of the ordinary on the FMS display, the flight crew did not realize that there was insufficient fuel on board.

2.2.2 Checklist items

The aircraft manufacturer's Beechcraft *Pilot's Check List—Normal Procedures*, which is carried in the aircraft but not used routinely, contains 3 items that refer to fuel quantity after the PREFLIGHT INSPECTION; 2 of these items are in checks that are to be conducted before takeoff. However, these 2 pre-takeoff items have been omitted from the company-developed, laminated *Normal Checklist B-200 G1000* that had been drawn up from the Keewatin Air SOPs.

During the occurrence flight, the flight crew was referring to the laminated *Normal Checklist B-200 G1000*. Both the AFTER START checklist and the CRUISE checklist have an item related to fuel.

The printed response to the FUEL QUANTITY challenge item on the plasticized *Normal Checklist B-200 G1000* AFTER START checklist is SUFFICIENT/BALANCED. The checklist item prompts the pilot to compare the fuel quantity gauge indications to the fuel quantity required for the flight. While performing the FUEL QUANTITY item on the AFTER START checklist, the captain responded to the FO's prompt with the rote response that the fuel was sufficient, without looking at the fuel gauges. The checklist item also did not trigger the FO to recall that the aircraft had not been fuelled. Consequently, the aircraft departed CYWG with insufficient fuel on board to complete the planned flight.

The SOPs require periodic checks of the instrument displays and controls at least every 30 minutes during cruise. Therefore, at least 2 scans should have been completed in the 1st hour of the occurrence flight. Although some level of cockpit scan was likely conducted during the flight, examination of the fuel quantity indicators was not included in these scans. When flying as FO before being upgraded, the captain was not accustomed to including the fuel quantity gauges in his cockpit scans. In addition, the cockpit layout of the Beechcraft B200 is such that, from the right seat, the indicators are partially obscured when the left seat pilot's hands are on the control wheel. In this occurrence, neither the captain nor the FO examined the fuel quantity indicators when conducting checklist items referring to fuel quantity.

The flight crew did not detect that there was insufficient fuel because the gauges had not been included in the periodic cockpit scans.

2.2.3 Progressive fuel calculation

Normally the progressive fuel calculation is performed as part of the CRUISE checklist, when the aircraft is level in cruise. However, neither the cruise procedure in the SOPs nor the operational flight plan (OFP) provide guidance as to how the calculation is to be performed.

Based on a fuel consumption of 800 pounds per hour, a climb and level-off at flight level (FL) 250 would require approximately 250 pounds of fuel.

On the occurrence flight, the captain made the fuel calculation roughly 8 nautical miles (NM) after takeoff, while the aircraft was still in the climb.

2.2.3.1 Fuel required

When performing a progressive fuel calculation, the number entered in the Fuel Required box in the OFP should be the initial quantity of fuel required to carry out the flight, minus the quantity of fuel consumed up to that point in the flight.

In this occurrence, the captain entered 2456 pounds (the initial quantity of fuel determined by flight planning) in the Fuel Required box instead of 2206 pounds (the initial quantity of fuel required minus 250 pounds for the climb).

2.2.3.2 Fuel remaining

When performing a progressive fuel calculation, the value entered in the Fuel Remaining box of the OFP should be obtained from the fuel quantity indicators.

In this occurrence, after engine start, the fuel quantity indicators were not checked to verify the fuel quantity remaining. The investigation was unable to determine with certainty how the Fuel Remaining value of 2206 pounds was obtained.

The investigation calculated the initial fuel quantity to be between 1300 and 1600 pounds. If 250 pounds is subtracted from those quantities, the fuel quantity indicators would have been indicating a total fuel quantity between 1050 and 1350 pounds.

By comparing the fuel required value of 2206 pounds with the indicated fuel quantity remaining value of 1050 to 1350 pounds, it would have been apparent that there was insufficient fuel remaining to complete the flight. This should have prompted closer examination of the progressive fuel calculation. However, the flight crew did not note this discrepancy.

When the flight crew performed the progressive fuel calculation, they did not confirm the results against the fuel gauges and therefore their attention was not drawn to the low-fuel state at a point that would have allowed for a safe landing.

2.3 Crew response

At 1813, when the left fuel pressure (L FUEL PRESS) warning light illuminated, the flight crew realized that the aircraft would not make it to CYYQ, and it was at that moment that the FO realized that he had forgotten to have the aircraft refuelled. The crew declared an emergency with the Winnipeg Area Control Centre (ACC). The flight crew was startled by the fuel exhaustion situation, and their management of the emergency subsequently deteriorated as they were faced with a the higher and unexpected workload owing to the impending fuel exhaustion and imminent power loss of one and, eventually, both engines.

The flight crew had little time to prepare for the forced approach and immediately prioritized the selection of a suitable alternate airport. Even though the decision had been made to divert to Gillam Airport (CYGX), Manitoba, the aircraft continued to fly on a heading toward CYYQ for about 2 minutes.

When the left engine lost power, the flight crew followed the procedure in the *Emergency and Abnormal Procedures Quick Reference Handbook* (QRH) to shut down the engine.

However, from 1815 to 1821, the left propeller continued to windmill at speeds between 1300 and 2000 rpm. It is likely that the propeller control lever had not been moved completely into the feather position.

At 1815:32, the FO programmed the FMS to display a track to CYGX on the captain's FMS. The FO instructed the captain to turn right and fly the track to CYGX. Only when the FO moved the heading bug on the FMS display did the captain turn the aircraft toward CYGX.

Still feeling the effect of the startle response to the fuel emergency, the captain quickly became task saturated, which led to an uncoordinated response by the flight crew, delaying the turn toward CYGX, and extending the approach.

The drag produced by the windmilling propeller explains the decaying airspeed and the difficulty the captain was experiencing controlling the aircraft. Although, the captain was attempting to descend to intercept an acceptable approach angle to CYGX, the windmilling propeller likely contributed to a rate of descent that was higher than expected, which at times approached 6000 fpm.

During the later stages of the descent, a vertical navigation (VNAV) profile was obtained to CYGX. However, the windmilling left propeller likely increased the difficulty of maintaining the descent path. At times, the aircraft was descending below the VNAV path and the airspeed was deteriorating. Observing that the captain was encountering difficulty maintaining airspeed and controlling the descent rate, the FO took control and was able to increase the airspeed and control the aircraft. When the aircraft was at 2800 feet above sea level (ASL), the left propeller stopped rotating, indicating that the blades had moved to the feather angle. A successful forced landing following the VNAV path would likely have been attainable if the right engine had continued to function.

However, the right engine lost power due to fuel exhaustion when the aircraft was 1 NM from Runway 23. From that position, a successful forced landing on the intended runway was no longer possible and, as a result, the aircraft touched down on the ice surface of Stephens Lake, short of the runway.

2.4 Line indoctrination

The occurrence flight was designated on the schedule as a line indoctrination training flight. However, the FO had not received the records from the captain's previous line indoctrination training. During such flights, as with any flight conducted with more than 1 pilot, the roles and responsibilities of each flight crew member must be well defined; otherwise, roles can become unclear and decisions may not be made quickly.

In this occurrence, the FO believed that the captain was the pilot-in-command (PIC). However, in accordance with Keewatin Air policy, because the FO was the providing line indoctrination training to the captain, the FO should have assumed the PIC role. If procedures are not developed to instruct pilots on their roles and responsibilities during line indoctrination flights, there is a risk that flight crew members may not participate when expected or may work independently towards different goals.

2.5 Emergency response

Winnipeg ACC notified the on-call airport operator at CYGX of the fuel emergency at 1820. The on-call operator arrived at the scene at 1826, 2 to 3 minutes after the aircraft had come to rest. The aircraft occupants declined medical attention and informed the operator that there was no risk of fuel leakage or fire.

The CYGX on-call operator notified emergency medical services (EMS) and the fire department at 1921 and 1922, respectively (about 1 hour after intitial notification by the ACC), and EMS arrived on site within about 2 minutes.

Because EMS and the fire department were not notified immediately about the declared emergency, they were not on site before the aircraft arrived at CYGX.

3.0 FINDINGS

3.1 Findings as to causes and contributing factors

These are conditions, acts or safety deficiencies that were found to have caused or contributed to this occurrence.

1. When the captain asked if the aircraft was ready for the flight, the first officer replied that it was, not recalling that the aircraft required fuel.
2. While performing the FUEL QUANTITY item on the AFTER START checklist, the captain responded to the first officer's prompt with the rote response that the fuel was sufficient, without looking at the fuel gauges.
3. The aircraft departed Winnipeg/James Armstrong Richardson International Airport with insufficient fuel on board to complete the planned flight.
4. The flight crew did not detect that there was insufficient fuel because the gauges had not been included in the periodic cockpit scans.
5. When the flight crew performed the progressive fuel calculation, they did not confirm the results against the fuel gauges, and therefore their attention was not drawn to the low-fuel state at a point that would have allowed for a safe landing.
6. Still feeling the effect of the startle response to the fuel emergency, the captain quickly became task saturated, which led to an uncoordinated response by the flight crew, delaying the turn toward Gillam Airport, and extending the approach.
7. The right engine lost power due to fuel exhaustion when the aircraft was 1 nautical mile from Runway 23. From that position, a successful forced landing on the intended runway was no longer possible and, as a result, the aircraft touched down on the ice surface of Stephens Lake, short of the runway.

3.2 Findings as to risk

These are conditions, unsafe acts or safety deficiencies that were found not to be a factor in this occurrence but could have adverse consequences in future occurrences.

1. If procedures are not developed to instruct pilots on their roles and responsibilities during line indoctrination flights, there is a risk that flight crew members may not participate when expected, or may work independently towards different goals.

3.3 Other findings

These items could enhance safety, resolve an issue of controversy, or provide a data point for future safety studies.

1. Because emergency medical services and the fire department were not notified immediately about the declared emergency, they were not on site before the aircraft arrived at Gillam Airport.

4.0 SAFETY ACTION

4.1 Safety action taken

4.1.1 Keewatin Air LP

After the occurrence, Keewatin Air LP carried out an internal investigation and issued a safety bulletin dated 03 May 2019, to pilots and flight coordinators (Appendix B). The bulletin detailed the actions to be taken by the flight crews when conducting the FUEL QUANTITY item of the AFTER START check. On 28 June 2019, Keewatin Air LP updated its Normal Checklist B-200 G1000 to reflect the changes specified in the safety bulletin.

The bulletin also clarified the fuel status information that flight crews are to provide the flight coordinator after departure, and after the progressive fuel calculation.

4.1.2 Town of Gillam

The Gillam RCMP (Royal Canadian Mounted Police) and Town of Gillam officials held a post-occurrence briefing and invited TSB investigators to attend. The briefing revealed a number of concerns, one of which was the delayed activation of emergency services. As a result, Town of Gillam officials reviewed the emergency response plan and prepared the *Gillam Airport Emergency Response Quick Reference* document. The document details the priority in which agencies should be notified, and actions that should be taken by the on-call airport operator when notified of an aviation emergency or incident.

This report concludes the Transportation Safety Board of Canada's investigation into this occurrence. The Board authorized the release of this report on 03 June 2020. It was officially released on 27 July 2020.

APPENDICES

Appendix A – *Normal Checklist B-200 G1000* (laminated)

NUNAVUT LIFELINE

NORMAL CHECKLIST B-200
G1000
January 10, 2019

****JOURNEY LOG, LICENCES, DOCUMENTS ON BOARD?*****

BEFORE START

- CARRY OVER AND CONFIRMATION OF NEXT DUE MAINTENANCE ITEMS/MEL DEFERRALS......CONFIRM
- FLIGHT NURSE READY?..........CONFIRM
- PARK BRAKE..........AS REQUIRED
- EXTERNALS..........2 CAPS/ CLEAN WING
- BATTERY.SWITCH..........ON (MIN: 20 V GPU/ 23 V BATTERY)
- (GPU)..........CONNECT (28.25 +/- 0.25 v)

- DOOR LIGHT..........EXTINGUISHED
- BEACON / NAV LIGHT..........ON
- PROP AREA..........CLEAR ON #___
- PROPS..........FULL FORWARD
- START ENGINE

"BEFORE START CHECKS COMPLETE"

AFTER START

- GPU..........DISCONNECTED
- FUEL QUANTITY..........SUFFICIENT/BALANCED
- CURRENT LIMITERS..........CHECKED
- GENERATORS..........BOTH ON LINE
- AVIONICS MASTER..........ON
- [BRAKE DE-ICE..........AS REQUIRED]
- PROP SYNC..........ON
- STANDBY BATTERY..........ARMED
- STANDBY INSTRUMENTS..........CHECKED, NO FLAGS
- ENGINE INSTRUMENTS..........GREEN/NORMAL
- TRIM TABS..........SET 3 WAYS
- PRESSURIZATION..........SET FOR TRIP
- FLAPS..........SET FOR TAKE-OFF
- BLEED AIR..........INSTR & ENVIR ON
- CABIN TEMP / MODE..........AUTO
- VENT BLOWER..........AUTO
- SUCTION/PNEUMATIC..........CHECKED
- MEDICAL INVERTER..........ON
- 0^2 SYSTEM READY HANDLE...PULL ON / CHECK LVL
- FLIGHT CONTROLS..........FREE/CORRECT
- AUTOFEATHER (first flight of the day)..........TEST

"AFTER START CHECKS COMPLETE"

CALL FOR CLEARANCE/AIRPORTADVISORY

FLIGHT INSTRUMENTS & AVIONICS

- ADF..........SET, IDENTIFIED
- FMS FLIGHT PLANNING..........CONFIRMED
- TRANSPONDER..........CODE/STBY
- TCAS..........UNRESTRICTED & 12 NM
- RADAR.......... STBY
- RADAR ALTIMETER..........TESTED
- ANNUNCIATORS & ALERTS..........CHECKED
- ALTITUDE SELECTOR..........______SET/**ALTS**
- FLIGHT DIRECTOR..........SET LEFT/RIGHT
- AFCS MODES..........__TO/HDG/**ALT S**
- YAW DAMPER..........OFF
- ALTIMETERS....____"SET LEFT&CENTER/____SET RIGHT"
- INDICATED ALTITUDE ....."____ LEFT & CENTER/RIGHT"
- V-SPEEDS..........____SET & INDICATING
- ACCELERATION ALTITUDE________"SET ON THE BARO"
- CDI/TRACK ....__________NEEDLES/ COURSE__**SET**
- HEADING..........____MAGNETIC/TRUE
- RMI SELECTORS..........________SET
- INSET MAP RANGE..........TRAFFIC 2 & 12 NM
- VHF/NAV'S ....TUNED
- TAKE OFF BRIEFING..........COMPLETE

"FLIGHT INSTRUMENTS &AVIONICS CHECKS COMPLETE"

CALL FOR TAXI INSTRUCTIONS/TAXI CALL

TAXI & BEFORE TAKEOFF

- FLIGHT NURSE READY?..........CONFIRM
- TAXI LIGHT..........ON
- CABIN SIGNS..........ON
- BRAKES..........CHECK
- FLIGHT INSTRUMENTS..........CHECKED
- ALTIMETERS..........X-CHECKED
- PROPS..........CYCLE
- ICE VANES..........AS REQUIRED
- AUTO FEATHER..........ARMED

- RADAR..........AS REQ'D
- ICE PROTECTION..........5 HOT + WINDOWS
- LIGHTS ....SET FOR TAKE-OFF (LDG/TAXI/NAV/BCN/[RECOG]/STROBES)
- AUTO-IGNITION..........ARMED
- ANNUNCIATOR LIGHTS..........CONSIDERED
- RWY HDG __(HSI)..........CONFIRMED
- EXTERNALS..........2 CAPS CLEAN WING L/R
- [WING LOCKERS..........SECURE L & R]

"TAXI & BEFORE TAKEOFF CHECKS COMPLETE"

AFTER TAKE OFF

- GEAR..........UP
- LANDING & TAXI LIGHTS..........OFF
- FLAPS..........UP
- YAW DAMPER & AUTOPILOT..........ON/AS REQ'D
- CLIMB POWER..........SET
- ENGINE INSTRUMENTS..........CHECK
- PROP SYNC..........ON
- ICE VANES..........AS REQ'D
- ICE PROTECTION..........AS REQ'D
- PRESSURIZATION..........CHECKED
- [AFT BLOWER..........AS REQ'D]
- EXTERNAL..........CHECKED
- AUTOFEATHER..........OFF
- TIME OFF..........RECORD

"AFTER TAKE OFF CHECKS COMPLETE"

10,000' UP

- LIGHTS..........[RECOG + STROBE OFF]
- MINIMUMS..........OFF
- CABIN SIGNS..........AS REQ'D
- PRESSURIZATION..........ON SCHEDULE
- 0^2 SYSTEM READY HANDLE..........CONFIRM ON
- TIME ....PASSED TO COMPANY

"10,000' CHECKS COMPLETE"

TRANSITION ALTITUDE/FL180

- ALTIMETERS...29.92" SET LEFT & CENTER /SET RIGHT
- PRESSURIZATION..........CHECKED

"FL 180 CHECKS COMPLETE"

CRUISE

- CRUISE POWER..........SET
- ENGINE INSTRUMENTS..........GREEN&NORMAL
- ELECTRICAL LOAD..........CHECKED
- FUEL.......... PROGRESSIVE FUEL Calc.
- ENVIRONMENTAL..........CHECK WITH NURSE
- PRESSURIZATION..........HOLDING

"CRUISE CHECKS COMPLETE"

TRAFFIC ADVISORY
LOG BOOK ENTRIES
TREND MONITOR

DESCENT

- ALTITUDE SELECTOR…SET
- PRESSURIZATION…SET
- ICE PROTECTION…AS REQUIRED
- RAIM PREDICTION…COMPLETED
- APPROACH BRIEFING…COMPLETED
- V-SPEEDS…SET

"DESCENT CHECKS COMPLETE"
TRAFFIC ADVISORY

18,000'

- ALTIMETERS.."____" SET LEFT & CENTER /SET RIGHT
- CABIN SIGNS…ON
- ICE VANES…EXTENDED

"18,000' CHECKS COMPLETE"
TRAFFIC ADVISORY CALL

APPROACH

- AUTO FEATHER…ARMED
- APPROACH MINIMUMS…______SET
- [RECOG] / STROBES…ON
- ALTIMETERS…CROSS CHECKED
- PRESSURIZATION…CHECKED
- CABIN SIGNS…ON
- FLIGHT DIRECTOR…SET L/R
- NAV & APPROACH AIDS…______SET/ X-CHECK
- HEADING… MAGNETIC/TRUE

"APPROACH CHECKS COMPLETE"
ADVISORY CALL COMMENCING APPROACH

LANDING

- PROPS…FULL FWD
- GEAR…DOWN / 3 GREEN
- LIGHTS…AS REQUIRED
- FLAPS…DOWN
- YAW DAMPER/AUTOPILOT…OFF

"LANDING CHECKS COMPLETE"
CALL FINAL

AFTER LANDING

- AUTO IGNITION/AUTO FEATHER…OFF
- LIGHTS…SET FOR TAXI
- ICE PROTECTION…OFF
- TRIM TABS…SET
- FLAPS…UP
- TRANSPONDER…VFR & STBY
- WX RADAR…STANDBY
- NAV AIDS…SET NEXT LEG
- FUEL BURN…NOTED
- TIME DOWN…NOTED

"AFTER LANDING CHECKS COMPLETE"
CALL DOWN AND CLEAR/ CONTACT GROUND

CIRCUITS

AFTER TAKE OFF

- GEAR…UP
- LANDING & TAXI LIGHTS…OFF
- FLAPS…UP
- YAW DAMPER…ON
- CRUISE POWER…SET

DOWNWIND

- BRIEFING…COMPLETED
- ALTIMETER…SET
- AUTO FEATHER…ARMED
- YAW DAMPER…OFF
- FLAPS…AS REQUIRED

LANDING

- PROPS…FULL FWD
- GEAR…DOWN / 3 GREEN
- LIGHTS…AS REQUIRED
- FLAPS…AS REQUIRED
- YAW DAMPER…OFF

"LANDING CHECKS COMPLETE"
CALL FINAL

SHUTDOWN

- TIME DOWN…CONFIRMED
- PARK BRAKE…AS REQ'D
- STBY BOOST PUMPS & X-FEED…OFF
- AVIONICS MASTER…OFF
- TAXI LIGHT…OFF
- PROP SYNC…OFF
- STANDBY BATTERY…OFF
- MEDICAL INVERTER…OFF
- CABIN TEMP / MODE…OFF
- VENT BLOWER…AUTO
- BLEED VALVES…OFF
- O^2 SYSTEM READY HANDLE…PUSH(LAST FLIGHT OF THE DAY)
- OVERHEAD LIGHTS…AS REQUIRED
- CABIN SIGNS…OFF
- CURRENT LIMITERS…CHECKED
- ITT (1 MIN)…STABILIZED

- CONDITION LEVERS…CUT OFF
- PROP LEVERS (<30%)…FEATHER
- BATTERY VOLTAGE (10%)…CHECKED
- BATTERY / GENERATORS…GANG BAR OFF
- STANDBY INSTRUMENTS…OFF
- CONTROL LOCK…INSTALLED
- PARK BRAKE/CHOCKS…AS REQUIRED

"SHUT DOWN CHECKS COMPLETE"
SWEEP PROPS- PLUGS-PROP TIES-ENG TENTS

PRESSURIZATION CONTROLLER

SETTING FOR LANDING

CLOSEST ALTIMETER SETTING	ADD TO AIRPORT ELEVATION
28.30	+ 2100
28.40	+ 2000
28.50	+ 1900
28.60	+ 1800
28.70	+ 1700
28.80	+ 1600
28.90	+ 1500
29.00	+ 1400
29.10	+ 1300
29.20	+ 1200
29.30	+ 1100
29.40	+ 1000
29.50	+ 900
29.60	+ 800
29.70	+ 700
29.80	+ 600
29.90	+ 500
30.00	+ 400
30.10	+ 300
30.20	+ 200
30.30	+ 100
30.40	0
30.50	- 100
30.60	- 200
30.70	- 300
30.80	- 400
30.90	- 500

Appendix B – Keewatin Air LP Safety Bulletin 03 May 2019

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KIVALLIQ AIR NUNAVUT LIFELINE

KEEWATIN AIR LP

TO: ALL PILOTS AND FLIGHT COORDINATORS

FROM:

DATE: May 3, 2019

RE: **SAFETY BULLETIN**

The investigation regarding the occurrence involving one of Keewatin Air's King Air 200s on April 24, 2019 is completed, however, the implementation phase of our Corrective and Preventative Actions (CPAs) is still ongoing. We have implemented some Corrective and Preventative Actions (CPAs) that will be effective immediately:

1. Actioning of the Checklist

   a) When actioning the Checklist, in accordance with your initial and/or annual recurrent flight training, all gauges, switches or buttons must be visually confirmed before considering the item as complete on the Checklist.

   b) During the "Fuel Quantity and Balance" Checklist item, the Challenge and Response will be:

   Pilot Flying (PF): "_______LBS. SUFFICIENT AND BALANCED". The PF will visually look at both fuel gauges, confirm the fuel amount, that it is sufficient, and that the fuel in both wings is balanced, and read out the fuel number in pounds (LBS).

   Pilot Monitoring (PM): "_______LBS CONFIRMED". The PM will visually look at both fuel gauges, confirm the fuel amount, that it is sufficient, and that the fuel in both wings is balanced, and read out "CONFIRMED". If there is a discrepancy between what the PF has advised and the fuel gauges, it is to be rectified immediately at this point.

   Example:

   Pilot Flying (PF): **"2,600 LBS. SUFFICIENT AND BALANCED"**

   Pilot Monitoring (PM): **"2,600 LBS CONFIRMED"**

2. Notification to the Flight Coordinator

   a) During initial contact to the Flight Coordinator after departure, after providing pertinent information such as departure time, ETA, etc, flight crews will continue to include fuel on board, however, the fuel quantity shall be visually confirmed by the flight crew via the fuel gauges and provided **in pounds (LBS), not hours.** The Flight Coordinator will document this on the Flight Watch Form under the "Fuel On Board" column.

   b) On flight legs of more than one hour, flight crews will contact the Flight Coordinator via sat phone approximately halfway during flight to advise them of the progressive fuel status - **current fuel on board (in LBS) and confirmation of sufficient fuel to their destination.** The Flight Coordinator will add an extra column to the Flight Watch Form and include this Progressive Fuel data.

Source: Keewatin Air LP